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THE EFFECT OF MANDREL HEATING ON THE QUALITY OF THE PULTRUSION PROCESS

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Abstract

Pultrusion is one of the most cost efficient composite manufacturing processes in which constant cross sectional continuous composite profiles are produced. Recently, pultruded structures are foreseen to have potential for the replacement of conventional materials used in the construction industry. A consequence of the increasing usage of pultruded profiles in the construction industry requires detailed understanding of the mechanical behavior as well as the failure mechanism of the profile.

In the present study, the pultrusion of a UD glass/epoxy square tube is simulated by performing a coupled 3D Eulerian thermo-chemical analysis together with 2D quasi-static Lagrangian mechanical analysis. Tubular pultruded products require a mandrel to form the internal shape; hence, a mandrel configuration is included in the present simulations. The temperature and the degree of cure distributions at steady state are first obtained in the thermo-chemical analysis and afterwards used in the mechanical analysis in which the residual stresses and distortions are evaluated using the generalized plane strain elements in ABAQUS software. The effect of the mandrel heating on the product quality, which has not been addressed in the literature for this specific field of application, is investigated in terms of degree of cure distributions, residual stresses and distortions.

A schematic view of the pultrusion domain is shown in Fig. 1. Due to symmetry, only quarter of the domain is considered. The cross sectional details (the dimensions and the mesh) are given in Fig. 2. The process induced residual stresses and distortions are calculated using the cure hardening instantaneous linear elastic (CHILE) approach. The effective composite material properties are predicted by self consistent field micromechanics (SCFM) approach. The contour plots of the predicted in-plane stresses at the end of the process are depicted in Fig. 3. It is seen that the stress levels without using the mandrel heating are approximately 2 times larger than the ones with the mandrel heating. The reason is that the larger through thickness temperature and cure gradients for without mandrel heating case promote the residual stresses. Similarly, the residual distortions are also relatively high for the case in which there is no mandrel heating as compared to the ones with mandrel heating. Additionally, the final cure degree distribution varies between 0.90 and 0.96 over the cross section of the square tube with mandrel heating case, however the range for the case where there is no mandrel heating is between 0.86 and 0.93.

This work shows that the usage of the mandrel heating improves the quality of the product in terms of the final degree of cure, the residual stresses and distortions. The proposed process simulations put forward in the present work can be further extended. The process parameters including the temperature of the mandrel heaters can be optimized to maximize the degree of cure or minimize the process induced residual stresses and distortions at the end of the process. This would provide a deeper understanding of the process.

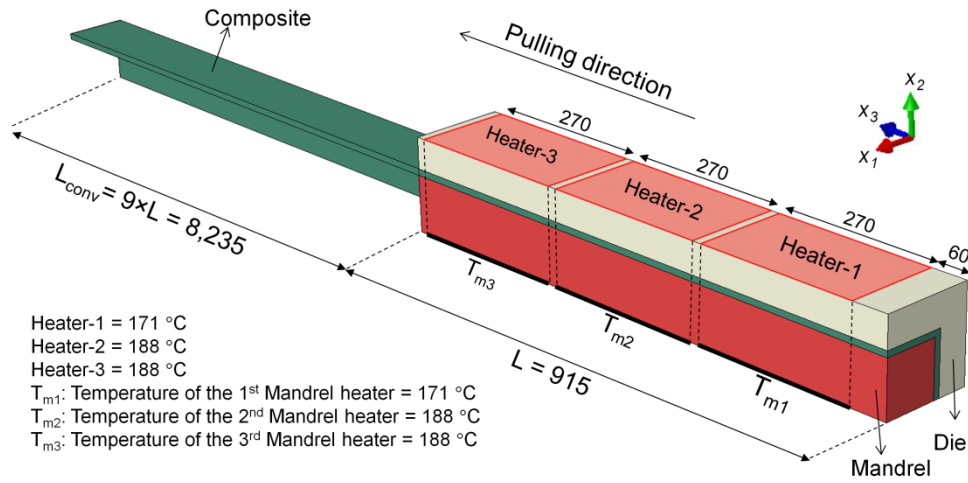


Figure 1. Schematic of the quarter pultrusion domain including the post die region. The length of the post die region is not scaled and all dimensions are in mm.

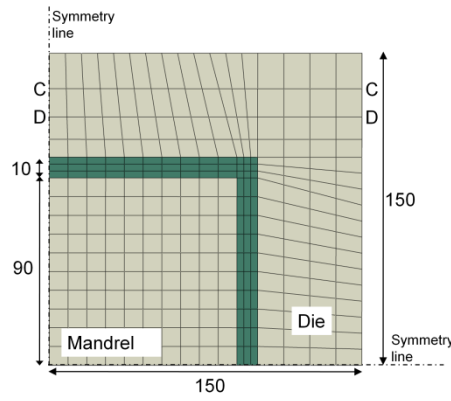


Figure 2. Details of the quarter cross section including the die, mandrel and the composite square tube. All dimensions are in mm.

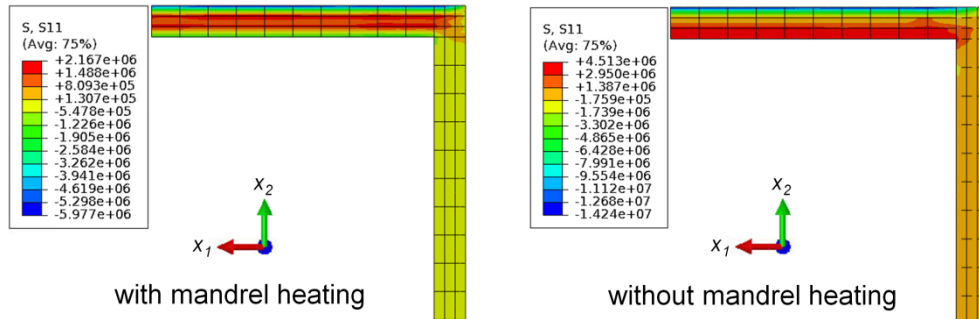


Figure 3. Undeformed contour plots of the normal stresses in x_1 -direction (S11) for pultruded square tube after cooling to ambient temperature. All units are in Pa.